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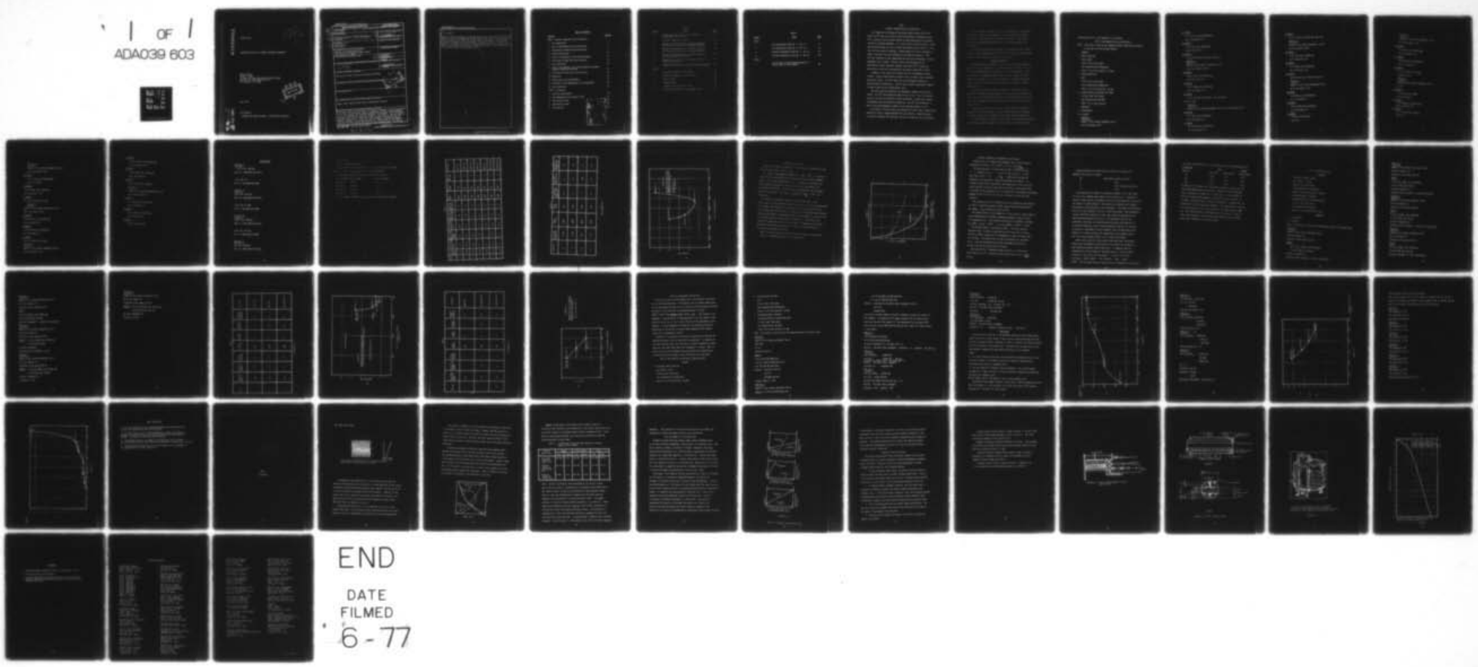

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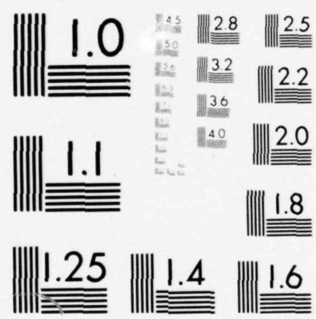
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# LABORATORY RESULTS OF LAUNDRY WASTEWATER TREATMENT

Mounir Botros
Walter C. Best
US Army Facilities Engineering Support Agency
Research and Technology Division
Fort Belvoir, VA 22060



April 1977



Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report relates the results of the chemical treatment of laundry wastewater in the lab, using different chemical coagulation and flocculation compounds i.e., iron, aluminum and lime used separately and together. The flocculation procedure using iron was discussed in detail. Also lime or lime and aluminum processes were tested. Finally the report suggests that the best way for chemical treatment is by using just only one chemical coagulation compound (Aluminum Sulfate) with polyelectrolytes as a flocculation aid (WT-2700) to lower the cost and simplify the design of the treatment plant. The optimum

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dosage of aluminum sulfate was estimated, and the best condition of the reaction especially for pH and temperature of the solution were fixed. Also includes the filtration process, the ideal sand filter and the designing of the media bed, the using of polymers as filtration aids. The type of filter structures were discussed. The gravity and pressure filters were concerned. The results of this effort indicate that the recycling of laundry wastewater at Army installations is not cost effective at the present time.

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## PART 1

## CHEMICAL COAGULATION AND FLOCCULATION

Iron Compounds as Phosphorus Precipitant both ferrous ($Fe^{2+}$) and ferric ($Fe^{3+}$) ions can be used in the precipitation of phosphorus with $Fe^{3+}$ a reaction can be written similar to that shown earlier for precipitation of aluminum phosphate. A 1:1 mole ratio of Fe:PO4 results. Since the molecular weight of iron is 55.85; the weight ratio of Fe:P is 1.8:1. Just as in the case of aluminum, a larger amount of iron is required in actual situations than the chemistry of the reaction predicts. With $Fe^{2+}$ the situation is more complicated and not fully understood. Ferrous phosphate can be formed. The mole ratio of Fe:PO4 would be 3:2. Experimental results indicate, however, that when $Fe^{2+}$ is used; the mole ratio of Fe:P will be essentially the same as when $Fe^{3+}$ is used.

A number of iron salts are available for use in phosphorus precipitation. These include ferrous sulfate, ferric sulfate, ferric chloride, and pickle liquor. All will lower the pH of wastewater because of neutralization of alkalinity. Pickle liquor contains substantial amounts of free sulfuric acid or hydrochloric acid.

Iron salts are most effective for phosphorus removal at certain pH values. For $Fe^{3+}$ the optimum pH range is 4.5 to 5.0. This is an unrealistically low pH, not attained in most wastewaters. Significant removal of phosphorus can be attained at higher pH. For $Fe^{2+}$ the optimum pH is about 8 and good phosphorus removal can be obtained between 7 and 8.

The acidity of ferrous salts, and especially pickle liquor, necessitates addition of lime or sodium hydroxide for good results. Where the water is aerated following $Fe^{2+}$ addition, the use of a base may not be necessary.

Ferric chloride is available in dry or liquid form. A crystalline form ($FeCl_3 \cdot 6H_2O$) is also available. The crystalline form weighs 60-64 $lb/ft^3$. The anhydrous form weighs 85-90 $lb/ft^3$. The typical liquid form contains 25-45 percent ferric chloride and weighs 11.2 - 12.4 lb/gal.

If iron salts are used for wastewater coagulation, a small amount of base, usually sodium hydroxide or lime is required to neutralize the acidity of these strong acid salts in soft waters.

POLYELECTROLYTES

Polyelectroyltes, or polymers, may be used in advanced wastewater plants as primary coagulants, as flocculation aids, as filter aids, or for sludge conditioning. In treatment of certain wastewaters, lime or alum alone or in combination may produce a fine or light floc which settles very slowly. If so, there probably is a polymer which, when used as an aid to lime or alum flocculation, will produce a rapidly settling floc.

Addition of the proper amount of polymer at the right point in treatment can greatly improve removals of both turbidity and phosphorus. Jar tests are of some value for preliminary screening, but plant scale tests must be employed for final selection and for determining optimum dosage rates.

Some polymers sold as a dry powder require special procedures for preparation of water solution. Specific instructions may be obtained from the supplier, but in general the following steps are necessary.

Thoroughly wet the polymer powder by means of a funnel type aspirator, add warm water and mix usually for about an hour, with gentle, slow

stirring until all of the polymer is in solution.

Test in the Chemical Lab by Using $FeCl_3$

NOTE: Every test in the lab was repeated several times and the figures in the test are the average figures.

Reagent

1. Ferric Chloride

   $FeCl_3$ $6H_2O$

   20 gm in one liter water

   The concentration 20,000 ppm/l

   every 1 ml of the solution = 20 ppm

2. Sodium hydroxide

   NaOH

   20 gm in one liter water

   the concentration 20,00o ppm/l

   every 1 ml of the solution = 20 ppm

3. polelectrolyte or polymer (WT 2700)

   0.1 gm in one liter water

   the concentration 100 ppm/l

   every 1 ml of the solution

Apparatus

1. Turbidimeter
2. ph meter

TEST NO. 1

sample of the laundry wastewater 125 ml

pH of the sample 10.75

by adding

14.5 ml $FeCl_3$ conc 20,000 ppm

pH of the water 3.75

by adding

2.5 ml NaOH conc 20,000 ppm

pH of the water 7.1

by adding

10 ml Wt 2700 conc.100 ppm light floc

TEST No. 2

Sample of the laundry wastewater 125 ml

pH of the sample 13.5 PH

by adding

18.5 ml $FeCl_3$ conc 20,000 ppm

pH of the water 3.75

by adding

3.25 ml NaOH conc 20,000 ppm

pH of the water 7.35

by adding

10 ml WT 2700 conc 100 ppm very good floc.

July 18, 1975

TEST No. 3

sample of the laundry wastewater 125 ml pH of the sample 13.25

by adding

14 ml FeCl3 conc 20,000 ppm

pH of the water 4.5

by adding

1.5 ml NaOH conc 20,000 ppm

pH of the water 7.25

by adding

10 ml WT-2700 conc. 100 ppm light floc.

TEST No. 4

Sample of the laundry Wastewater 125 ml

pH of the sample 13.05

by adding

15 ml $FeCl_3$ conc. 20,000 ppm

pH of the water 3.75

by adding

2.5 ml NaOH conc 20,000 ppm

pH of the water 7.50

by adding

10 ml WT 2700 conc 100 ppm light floc

TEST No. 5

Sample of the laundry wastewater 125 ml

pH of the sample 13.15

by adding

13 ml $FeCl_3$ conc 20,000 ppm

pH of the water 6

by adding

0.85 ml NaOH conc 20,000 ppm

pH of the water 7.5

by adding

10 ml WT 2700 100 ppm

bad floc.

TEST No. 6

Sample of the laundry wastewater 125 ml

pH of the sample 13.15

by adding

19 ml $FeCl_3$ conc 20,000 ppm

pH of the water 3.50

by adding

4.25 ml NaOH conc 20,000 ppm

pH of the water 7.5

by adding

10 ml WT 2700 conc 100 ppm

excellent floc.

TEST No. 7

Sample of the laundry wastewater 125 ml

pH 13.2

by adding

16 ml $FeCl_3$ conc 20,000

pH of the water 4

by adding

3.25 ml NaOH conc 20,000 ppm

pH of the water 7.8

by adding

10 ml WT 2700 conc 100 ppm

good floc

TEST No. 8

Sample of the laundry wastewater 125 ml

pH of the sample 13.35

by adding

14.3 ml $FeCl_3$ conc 20,000 ppm

pH of the water 6

by adding

1.15 ml NaOH conc 20,000 ppm

pH of the water 7.50

by adding

12 ml WT 2700 conc 100 ppm

TEST No. 9

Sample of the laundry wastewater 125 ml

pH of the sample 13.35

by adding

14.6 ml $FeCl_3$ conc 20,000 ppm

pH of the water 4.9

by adding

1.65 ml NaOH conc 20,000 ppm

pH of the water 7.5

by adding

12 ml WT 2700 conc 100 ppm

TEST No. 10

Sample of the laundry wastewater 125 ml

pH of the sample 13.3

by adding

15.45 ml $FeCl_3$ conc 20,000 ppm

pH of the water 3.94

by adding

2.55 ml NaOH conc 20,000 ppm

pH of the water 7.5

by adding

12 ml WT 2700 conc 100 ppm

TEST No. 11

Sample of the laundry wastewater 125 ml

pH of the sample 13.3

by adding

16 ml $FeCl_3$ conc 20,000 ppm

pH of the water 3.8

by adding

2.6 ml NaOH conc 20,000 ppm

pH of the water 7.8

by adding

12 ml WT 2700 100 ppm

## Calculation

TEST No. 8

$14.3 \times 20 = 286$ ppm

$286 \times 8 = 2288$ ppm/liter $FeCl_3$

$1.15 \times 20 = 23$

$23 \times 8 = 184$ ppm/liter NaOH

TEST No. 9

$14.6 \times 20 = 292$ ppm

$292 \times 8 = 2336$ ppm/liter $FeCl_3$

$1.65 \times 20 = 33$ ppm

$33 \times 8 = 264$ ppm/liter NaOH

TEST No. 10

$15.45 \times 20 = 309$ ppm

$309 \times 8 = 2472$ ppm/liter $FeCl_3$

$2.55 \times 20 = 51$ ppm

$51 \times 8 = 408$ ppm/liter NaOH

TEST No. 11

$16 \times 20 = 320$ ppm

$320 \times 8 = 2560$ ppm/liter $FeCl_3$

2.6 x 20 = 52

52 x 8 = 416 ppm/liter NaOH

The conc of WT-2700 solution in test 8, 9, 10, and the 11 the same amount 12 x .100 = 1.2 ppm and 1.2 x 8 = 9.6 ppm/liter.

The average turbidity of the laundry waste water 300 FTU.

| The turbidity after treatment | | pH after treatment |
|---|---|---|
| Test No. 8 | 20 FTU | 7.5 |
| Test No. 9 | 12 FTU | 7.5 |
| Test No. 10 | 7.0 FTU | 7.5 |
| Test No. 11 | 27 FTU | 7.8 |

Fig. 1 indicates different conc of $FeCl_3$ with differrent turbidity.

TABLE 1

| TEST NO. | pH of the raw waste-water | ml of $FeCl_3$ conc 20,000 ppm/l | pH of the water after adding $FeCl_3$ | ml of NaOH conc 20,000 ppm/l | pH of the water after adding NaOH | ml of WT-2700 conc. 100 ppm/l | ppm/l of $FeCl_3$ | ppm/l of NaOH | ppm/l of WT-2700 | Conclusion |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 13.15 | 13 | 6 | 0.85 | 7.5 | 10 | 2080 | 136 | 8 | Bad floc |
| 3 | 13.25 | 14.0 | 4.5 | 1.5 | 7.25 | 10 | 2240 | 240 | 8 | Light floc |
| 1 | 10.75 | 14.5 | 3.75 | 2.5 | 7.1 | 10 | 2320 | 400 | 8 | Light floc |
| 4 | 13.05 | 15 | 3.75 | 2.5 | 7.5 | 10 | 2400 | 400 | 8 | Light floc |
| 7 | 13.2 | 16 | 4 | 3.25 | 7.8 | 10 | 2560 | 520 | 8 | Good floc |
| 2 | 13.5 | 18.5 | 3.75 | 3.25 | 7.35 | 10 | 2960 | 520 | 8 | Very good floc |
| 6 | 13.15 | 19 | 3.5 | 4.25 | 7.5 | 10 | 3040 | 680 | 8 | Excellent floc |

TABLE 2

| TEST NO. | pH of the Wastewater | ppm/l $FeCl_3$ | ppm/l NaOH | Turbidity after treatment FTU | pH after adding $FeCl_3$ | pH after adding NaOH Final pH |
|---|---|---|---|---|---|---|
| 8 | 13.35 | 2288 | 184 | 20 | 6 | 7.5 |
| 9 | 13.35 | 2336 | 264 | 12 | 4.9 | 7.5 |
| 10 | 13.3 | 2472 | 408 | 7 | 3.94 | 7.5 |
| 11 | 13.3 | 2560 | 416 | 27 | 3.8 | 7.8 |

SEE FIGURE NO. 1

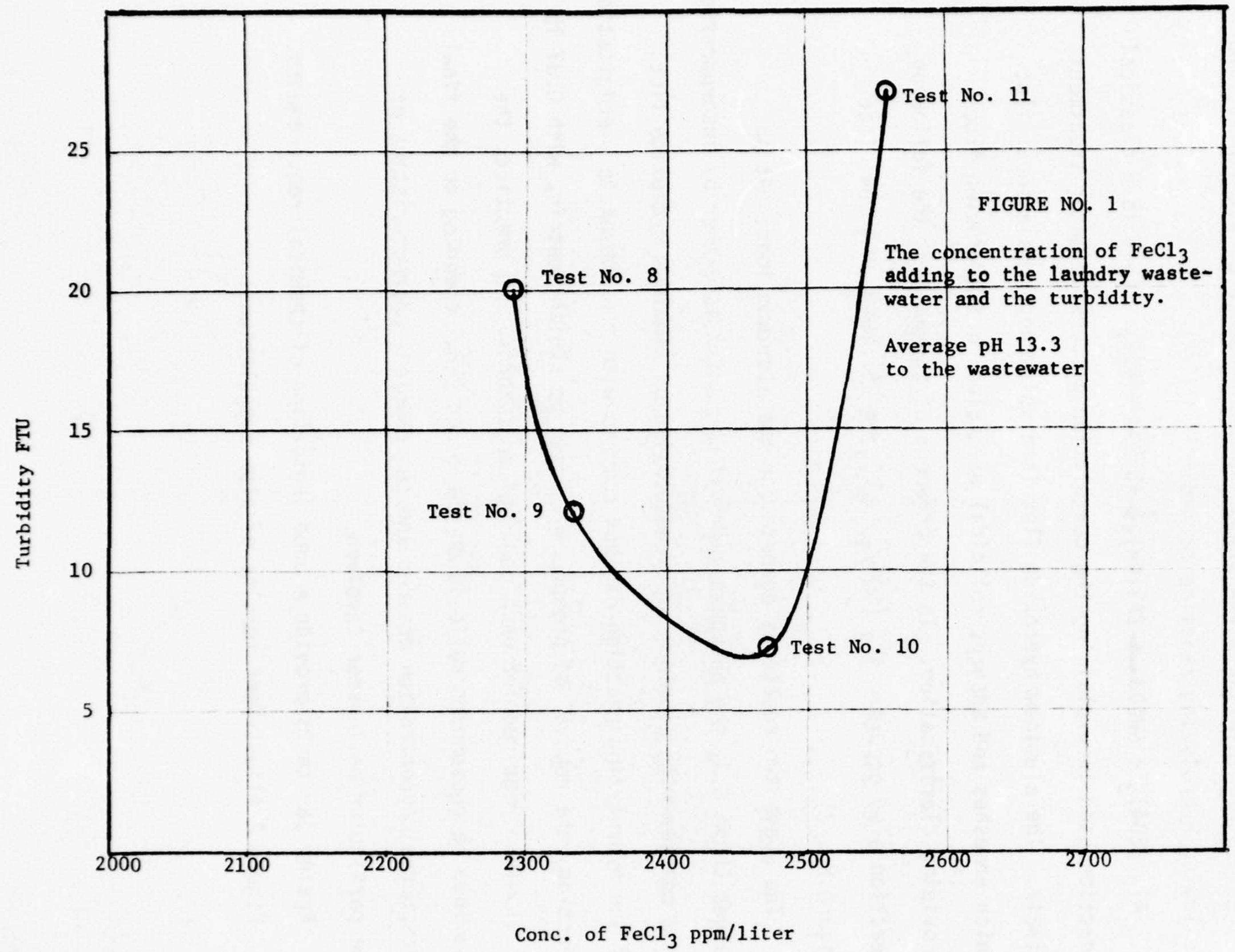



FIGURE NO. 1

The concentration of $FeCl_3$ adding to the laundry wastewater and the turbidity.

Average pH 13.3 to the wastewater

## Aluminum Coagulation

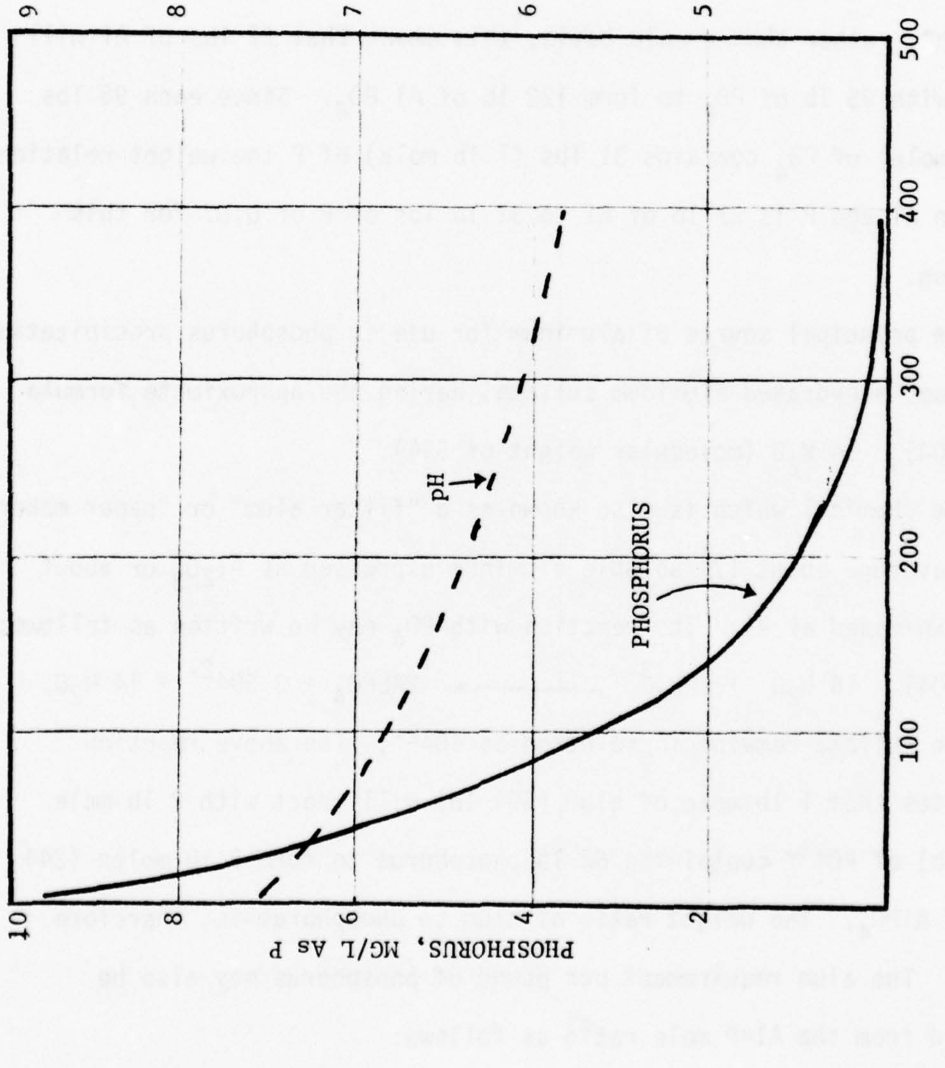
When alum is added to wastewater in the presence of alkalinity, the following hydrolyzing reaction occurs:

$Al_2\ (SO4)_3 + 6HCO3 \rightarrow 2Al(OH)_3\downarrow + 3\ SO4 + 6CO_2$. This is a classical reaction used in explaining the coagulation process in water treatment plants. The aluminum hydroxide floc is a voluminous, gelatinous floc which enmeshes and adsorbs colloidal particles on the growing floc providing clarification. In the presence of phosphates, the following reaction also occurs: $Al_2\ (SO4)_3 + {}_2PO_4 \rightarrow 2Al\ PO4\downarrow + 3\ SO4$ (see Figure No. 2)

The above two reactions compete for the aluminum ions. At pH values above 6.3, the phosphate removal mechanism is either by incorporation in a complex with aluminum or by adsorption on aluminum hydroxide floc. If the hydrolyzing reaction did not compete with the phosphate precipitation reaction, the removal of phosphorous would be stoichiometric, with 0.87 lb of aluminum required for each pound of phosphorus. In practice, the aluminum to phosphorus ratio is on the order 2-3, depending on the final phosphorus concentration desired and the chemical characteristics of the particular wastewater involved.

Again, jar tests provide a good indication of chemical requirements. Figure 2 illustrates results of alum coagulation.

FIGURE 2
Alum Coagulation of Sewage



Aluminum Compounds as Phosphorus Precipitants

Aluminum ions can combine with phosphate ions to form aluminum phosphate as follows: $Al^{3+} + PO4^{3-} \longrightarrow AlPO_4$.

The above equation indicates that the mole ratio for $Al = PO_4$ is 1 = 1. Inasmuch as the mole ratio of $P = PO_4$ is also 1 = 1, the mole ratio for Al = P is 1 = 1 or $\frac{Al}{P} = 1$ when both aluminum and phosphorus are expressed in terms of gram-moles or lb-moles. On a weight, rather than a mole basis, this means that 27 lbs of Al will react with 95 lb of $PO_4$ to form 122 lb of Al $PO_4$. Since each 95 lbs (1 lb-mole) of $PO_4$ contains 31 lbs (1 lb mole) of P the weight relationship between Al and P is 27 lb of Al to 31 lb lbs of P or 0.87 for this reaction.

The principal source of aluminum for use in phosphorus precipitation is "alum" a hydrated aluminum sulfate, having the approximate formula $Al_2\ (SO4)_3\ \ 14\ H_2O$ (molecular weight of 594).

The chemical which is also known as a "filter alum" or "paper maker's alum" average about 17% soluble aluminum expressed as $Al_2O_3$ or about 9.1% expressed as Al. Its reaction with $PO_4$ may be written as follows:

$$Al_2\ (SO4)_3\ \ 14\ H_2O\ +\ 2PO_4^{3-} \longrightarrow 2ALPO_4 + 3\ SO4^{2-} + 14\ H_2O.$$

The sulfate remains in solution as $SO4^{2-}$. The above reaction indicates that 1 lb-mole of alum (594 lb) will react with 2 lb-mole (190 lb) of $PO4^{3-}$ containing 62 lb phosphorus to form 2 lb moles (244 lb) of $AlPO_4$. The weight ratio of alum to phosphorus is, therefore 9.6:1. The alum requirement per pound of phosphorus may also be derived from the Al=P mole ratio as follows:

Mole ratio Al:P=1:1 therefore weight ratio Al:P = 27:31=0.87=1

Alum contains 9.1% Al. Therefore, alum required per lb of P = $\frac{0.87}{0.091}$ = 9.6 lb.

stumn and Morgan (3) state that the solubility of $AlPO_4$ is pH dependent and varies as follows:

| pH | Approximate solubility (mg/l) |
|---|---|
| 5 | 0.03 |
| 6 | 0.01 (minimum solubility) |
| 7 | 0.30 |

The optimum pH for removal of phosphorus probably lies in the range of 5.5 to 6.5, although some removal occurs above pH 6.5. , Addition of alum will lower the pH of wastewater because of neutralization of alkalinity and release of carbon dioxide. The extent of pH reduction will depend principally on the alkalinity of the wastewater. The higher the alkalinity, the less is the reduction in pH for a given alum dosage. Most wastewaters contain sufficient alkalinity so that even large alum dosages will not lower the pH below about 6.0 to 6.5. In exceptional cases of low wastewater alkalinity, pH reduction may be so great that addition of an alkaline substance, such as sodium hydroxide, soda ash, or lime will be required. Adjustment of the pH downward can be accomplished by the addition of sulfuric acid but this complicates the treatment process and it may be preferable simply to use a higher alum dosage.

Bench, pilot, and full scale studies have shown that considerably higher than stoichiometric quantities of alum usually are necessary to meet optimum phosphorus removal objectives. A competing reaction, responsible for the pH reduction mentioned above, at least partially accounts for the excess alum requirement. It occurs as follows:

$Al_2\ (SO4)_3 \bullet 14H2O + 6HCO3 \longrightarrow 2AL(OH)3 + 6CO_2 + 14H_2O + 3SO4^{2-}$. The following ratios of alum (9.1% Al) to phosphorus are believed

reasonably representative for alum treatment or municipal wastewater (4)

| P Reduction Required | Al:P Mole Ratio | Al:P Weight Ratio | Alum:P Weight Ratio |
|---|---|---|---|
| 75% | 1.38:1 | 1.2:1 | 13:1 |
| 85% | 1.72:1 | 1.5:1 | 16:1 |
| 95% | 2.3:1 | 2.0:1 | 22:1 |

To achieve 85% P removal from a washwater containing 11 mg/l of P the alum dosage needed would be (16) (11) = 176 mg/l or 1470 lb/$10^6$ gal. Alum is available in either dry or liquid form. It is available in dry form as either ground powder, or lump form in bags, barrels, or carloads. The ground form is used for dry feeding. It weighs 60 - 75 lbs/$ft^3$ and is only slightly by groscopic. The liquid form is a 50 per cent alum solution and is usually delivered in minimum loads of 4000 gal. The liquid form may be delivered by rail or truck. It must be stored and conveyed in corrosion resistant materials such as rubber lined steel, fiberglass or stainless steel.

## Test in the Chemical Lab

### Reagents

1. Aluminum Sulfate Solution

   $Al_2 (SO4)3 \cdot 18 H_2O$

   20 gm in one liter water

   the concentration 20,000 ppm/l

   every 1 ml of the solution = 20 ppm

2. Polyelectrolyte or polymer

   We used WT-2700 as flocculation aids

   0.1 gm in one liter water

   The concentration 100 ppm/l

   Every 1 ml of the solution 0.1 ppm

### Apparatus

1. Turbidimeter
2. pH meter

NOTE: The figures in the test are the average figures for several tests.

<u>TEST No. 1</u>

Sample of the laundry wastewater 100 ml

pH of the sample 13.3

Turbidity of the sample 400 FTU

<u>Adding</u>

16.5 ml $Al_2 (SO4)_3$ conc 20,000 ppm

12 ml WT-2700 conc 100 ppm

pH after treatment 7.5

Turbidity after treatment 7.3 light flocculation.

TEST No. 2

Sample of the laundry waste water 100 ml

pH of the sample 13.3

Turbidity of the sample 400 FTU

adding

17.2 ml $Al_2 (SO4)_3$ conc 20,000 ppm

12 ml WT 2700 conc 100 ppm

pH after treatment 7.2

Turbidity after treatment 3.8 good flocculation.

TEST No. 3

Sample of the laundry wastewater 100 ml

pH of the sample 13.3

Turbidity of the sample 400 FTU

Adding

18 ml $Al_2 (SO4)_3$ conc 20,000 ppm

12 ml WT-2700 conc 100 ppm

pH after treatment 6.6

Turbidity after treatment 3.1 very good flocculation.

TEST No. 4

Sample of the laundry wastewater 100 ml

pH of the sample 13

Turbidity of the sample 420 FTU

Adding

18 ml $Al_2 (SO4)_3$ conc 20,000 ppm

10 ml WT 2700 conc 100 ppm

pH after treatment 7.3 light flocculation.

TEST No. 5

Sample of the laundry wastewater 100 ml

pH of the sample 13.1

Turbidity of the sample 420 FTU

Adding

20 ml $Al_2 (SO4)_3$ conc 20,000 ppm

10 ml WT 2700 conc 100 ppm

pH after treatment 6   excellent flocculation

TEST No. 6

Sample of the laundry wastewater 100 ml

pH of the sample 9.5

Turbidity of the sample 250 FTU

Adding: 1 ml $Al_2 (SO4)_3$ conc 20,000 ppm

5 ml WT 2700 100 ppm

pH after treatment 7

Turbidity after treatment 1.5 FTU

TEST No. 7

Sample of the laundry wastewater 100 ml

pH of the sample 9.5

Turbidity of the sample 250 FTU

Adding: 1.5 ml $Al_2 (SO4)_3$ conc 20,000 ppm

5 ml WT 2700 conc 100 ppm

pH after treatment 6.5

Turbidity 2.5 FTU

TEST No. 8

Sample of the laundry wastewater 100 ml

pH of the sample 9.5

Turbidity of the sample 250 FTU

Adding: 2.0 ml $Al_2 (SO4)_3$ conc 20,000 ppm

5 ml WT 2700 conc 100 ppm

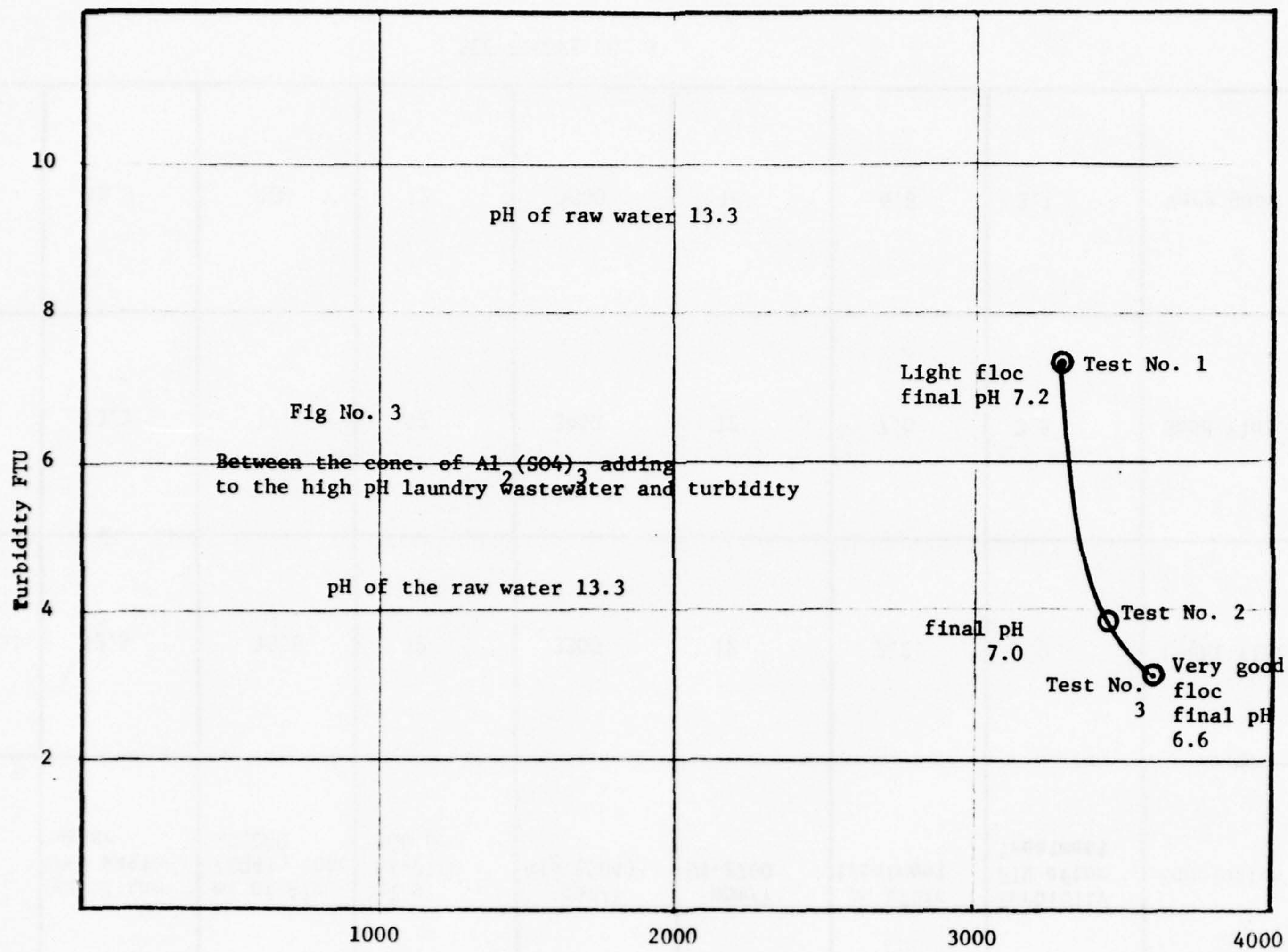
pH after treatment 6.0

Turbidity 3.5 FTU

TABLE 3

| TEST NO. | pH of the raw waste-water | ml of $Al_2(SO4)_3$ conc 20,000 | ml of WT-2700 100 ppm | ppm/l $Al_2(SO4)_3$ | ppm/l WT-2700 | pH after treatment | Turbidity FTU after Treatment | Conclusion |
|---|---|---|---|---|---|---|---|---|
| 1 | 13.3 | 16.5 | 12 | 3300 | 12 | 7.2 | 7.3 | Light floc. |
| 2 | 13.3 | 17.2 | 12 | 3440 | 12 | 7.0 | 3.8 | Good floc. |
| 3 | 13.3 | 18 | 12 | 3600 | 12 | 6.6 | 3.1 | Very good floc. |

SEE FIGURE NO. 3




Conc. of $Al_2(SO4)_3$ ppm/liter
FIGURE NO. 3

TABLE 4

| TEST NO. | pH of the raw waste-water | ml of $Al_2(SO4)_3$ conc. 20,000 | ml of WT-2700 100 ppm | ppm/l $Al_2(SO4)_3$ | ppm/l WT-2700 | pH after treatment | Turbidity after treatment | Conclusion |
|---|---|---|---|---|---|---|---|---|
| 6 | 9.5 | 1 | 5 | 200 | 5 | 7 | 3.5 | Good floc. |
| 7 | 9.5 | 1.5 | 5 | 300 | 5 | 6.5 | 2.5 | Very good floc. |
| 8 | 9.5 | 2 | 5 | 400 | 5 | 6 | 1.5 | Excellent floc. |

SEE FIGURE NO. 4

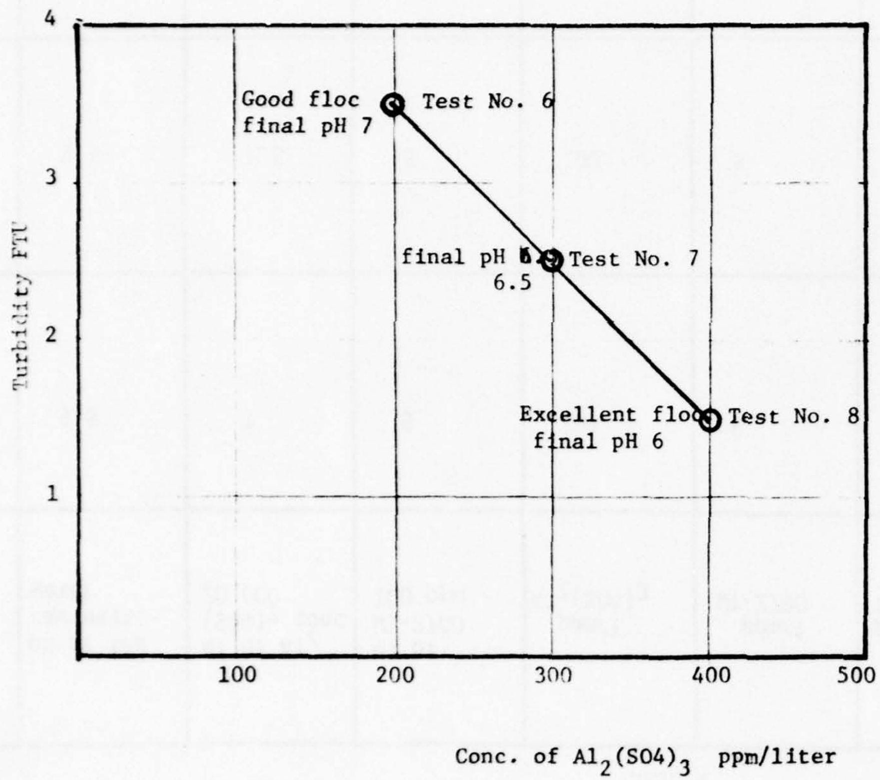



FIGURE NO. 4

FIGURE NO. 4

Between the conc. of $Al_2(SO4)_3$ adding to the low pH laundry waste water and turbidity.

pH of the low water 9.5

## Lime as a Phosphorus Precipitant

Calcium ion reacts with phosphate ion in the presence of hydroxyl ion to form hydroxyapatite. This material has a variable composition, but an approximate equation for its formation can be written as follows, assuming in this case that the phosphate present is $HPO_4^{2-}$

$3HPO4^{2-} + 5Ca^{2+} + 4OH^- \longrightarrow Ca_5(OH)(PO4) + 3H_2O$. The reaction is pH dependent. The solubility of hydroxyapatite is so low, however, that even at a pH as low as 9.0, a large fraction of the phosphorus can be removed. In lime treatment of wastewater, the operating pH may be predicated on the ability to obtain good suspended solids removal rather than on phosphorus removal.

Although it is possible to calculate an approximate lime dose for phosphorus removal, this is generally not necessary. In contrast to iron and aluminum salts, the lime dose is largely determined by other reactions that take place when pH of wastewater is raised. Only in waters of very low bicarbonate alkalinity would the phosphate precipitation reaction consume a large fraction of the lime added.

### Test in the Chemical Lab Using $Al_2(SO4)_3$ and CaO

### Reagent

1. Aluminum Sulfate Solution

   $Al_2(SO4)_3 \; 18\,H_2O$

   20 gm in one liter water

   The concentration 20,000 ppm/l

   Every 1 ml of the solution = 20 ppm

2. Calcium Oxide Solution

CaO

20 gm in one liter water

The concentration 20,000 ppm/l

Every 1 ml of the solution = 20 ppm

3. Polyelectrolyte or polymer

We used WT 2700 as flocculation aids

0.1 gm in one liter water

The concentration 100 ppm/l

Every 1 ml of the solution 0.1 ppm

NOTE: The figures in the test are the average figures for several tests.

TEST No. 1

Sample of the laundry wastewater 100 ml

Temp $52^{o}C$

pH 11.5

Turbidity 430 FTU

Adding

18 ml CaO 20,000 ppm/liter

3 ml $Al_2$ $(SO4)_3$ 20,000 ppm/liter

2 ml WT 2700 500 ppm/liter

Results: Turbidty 0.75 FTU

pH 11.4

Hardened 500 ppm

Friday, August 1, 1975

TEST No. 2

Sample of the laundry wastewater 100 ml

Adding 1- 12 ml CaO 20,000 ppm/liter

2- 2 ml $Al_2(SO4)_3$ 20,000 ppm/liter

3- 2 ml WT 2700 500 ppm/liter

Results: Turbidity of the water after treatment 2.25 FTU

pH 11.25

Hardness 400

We tried to use less amount of CaO for treatment to lower the figure of the hardness. The amount of the sample constant 100 ml laundry waste-water and the pH of the sample 11.7 the temperature of the sample 25$^{o}$C the turbidity of the sample 300 FTU and we used 1 ppm of WT 2700 solution in the sample.

TEST No. 1

5 ml $Al_2$(SO4)3 20,000 ppm

10 ml CaO 20,000 ppm 200 ppm

pH after $Al_2(SO4)_3$ 11.2 pH after CaO 11.9

Results: The water after treatment: Turbidity: 12 Hardness: 460 ppm $CaO_3$

TEST No. 2

6 ml $Al_2(SO4)_3$ 20,000 ppm

8 ml CaO 20,000 ppm 160 ppm

pH after $Al_2$ $(SO4)_3$ 10.4 pH after CaO 12

RESULTS: The water after treatment

Turbidity 9.2 Hardness 450

TEST No. 3

8 ml $Al_2$ $(SO4)_3$ 20,000 ppm

6 ml CaO 20,000 120 ppm

pH after Al2 (SO4)3 9.8 ph after CaO 11.9

Results: The water after treatment

Turbidity 8.00 Hardness 390

TEST No. 4

10 ml $Al_2(SO4)_3$ 20,000 ppm

2 ml CaO 20,000 ppm 40 ppm

pH after $Al_2(SO4)_3$ 8.2 pH after CaO 10.5

Results: The water after treatment

Turbidity Hardness 300

TEST No. 5

13 ml $Al_2(SO4)_3$ 20,000 ppm

1 ml CaO 4,000 = 4 ppm

Results: The water after treatment

Turbidity 5.5 Hardness 150 ppm as $CaCO_3$ (See Fig. 5)

## Conclusion

1. By using Ferric chloride in the treatment process for the laundry wastewater we must use a small amount of base, usually sodium hydroxide that means we shall use three chemical compounds (1) Ferric chloride, (2) Sodium hydroxide, and (3) WT-2700 as a flocculation aid. That means the cost goes up by using more chemical compound and complicates the design of the treatment plant.

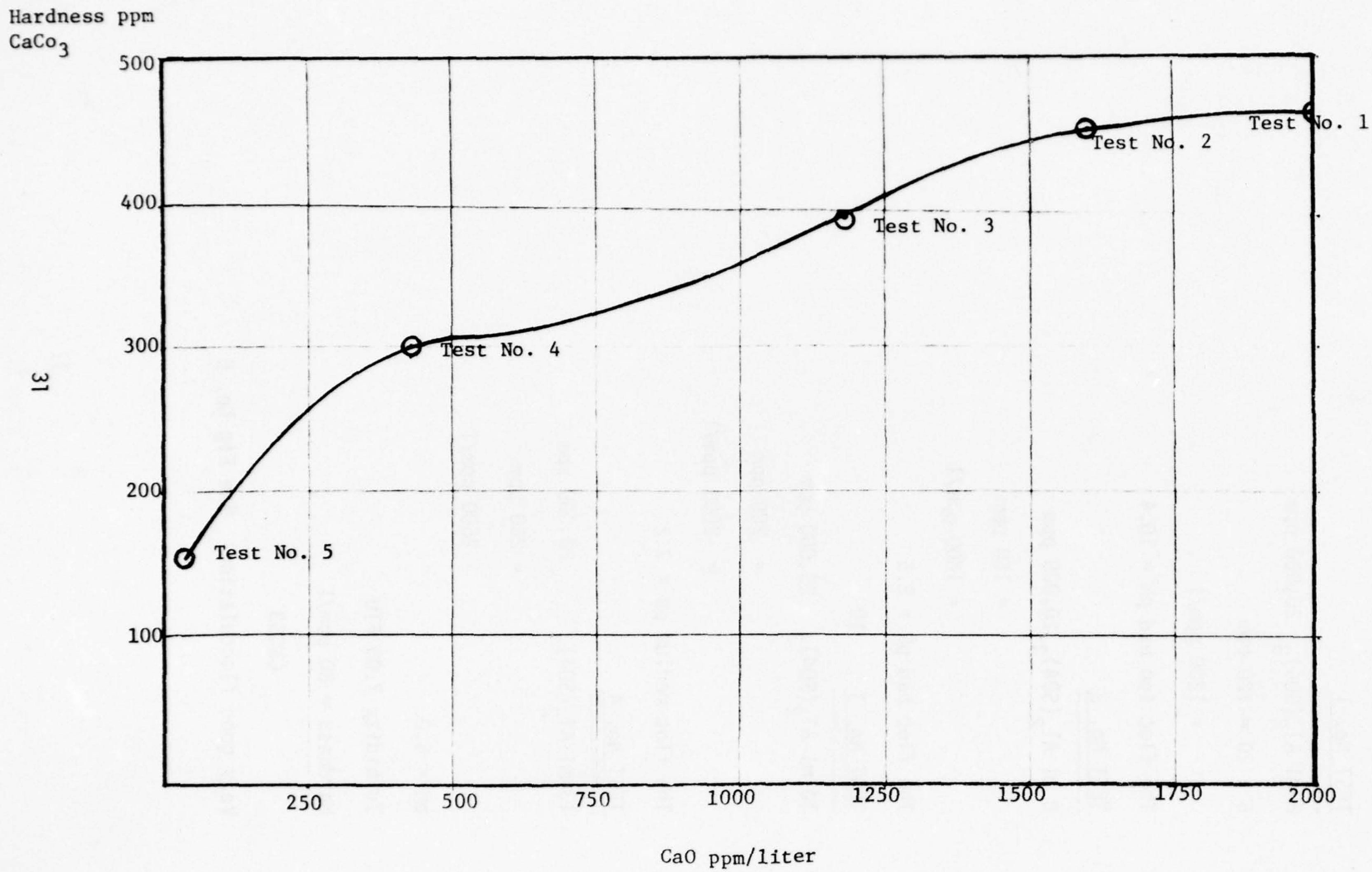
2. By using aluminum sulfate and lime we watched the hardness go up by using very small amount of lime (CaO) and also more chemical compound may be complicates the design of treatment plant.

3. The best method of treatment laundry wastewater is by using aluminum sulfate only to lower the cost by using one chemical compound and simplifying the design of treatment plant.

We run another test in the chemical lab by using $Al_2(SO4)_3$ only:

The amount of the sample constant in every test = 100 ml wastewater and the pH of the sample 11.7 and the amount of WT-2700 which added to the samples constant 10 ml 100 ppm/l for every sample.

FIGURE NO. 5


Hardness ppm
CaCo3
500
400
300
200
100
250
500
750
1000
1250
1500
1750
2000
Test No. 1
Test No. 2
Test No. 3
Test No. 4
Test No. 5
CaO ppm/liter

TEST No. 1

6 ml $Al_2(SO4)_3$ 20,000 ppm

6 x 20 = 120 ppm

= 1200 ppm/l

The floc too bad pH = 10.4

TEST No. 2

8 ml $Al_2(SO4)_3$ 20,000 ppm

= 160 ppm

= 1600 ppm/l

The floc bad pH = 8.5

TEST No. 3 10

10 ml $Al_2(SO4)_3$ 20,000 ppm

= 200 ppm

= 2000 ppm/l

The floc medium pH = 7.2

TEST No. 4

13 ml $Al_2(SO4)_3$ 20,000 ppm

= 260 ppm

= 2600 ppm/l

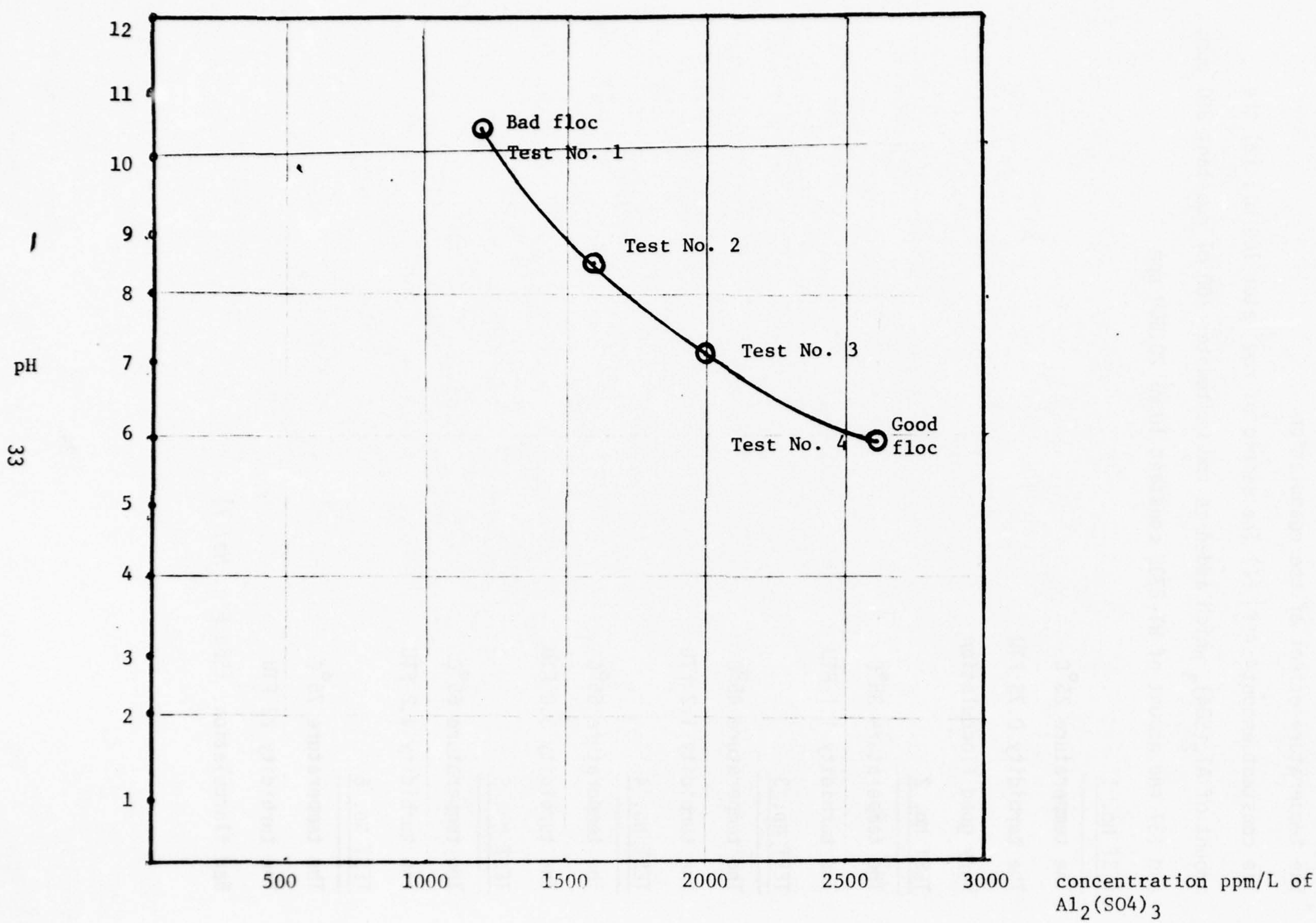
pH = 6.0

Turbidity 7.00 FTU

Hardness = 60 ppm/l

CaCO3

Very good flocculation See Fig No. 6



pH
12
11
10
9
8
7
6
5
4
3
2
1
500
1000
1500
2000
2500
3000
concentration ppm/L of
$Al_2(SO4)_3$
Bad floc
Test No. 1
Test No. 2
Test No. 3
Test No. 4
Good
floc


FIGURE NO. 6

The temperature effect of the coagulation

The constant amounts are: (1) The sample of raw water 100 ml; (2) the amount of $Al_2(SO4)_3$ which added to the wastewater 100 ml constant 260 ppm; and (3) the amount of WT-2700 constant 10 ml 20,000 ppm

TEST No. 1

The temperature 25°C

The turbidity 0.75 FTU

Very good flocculation

TEST No. 2

The temperature 35°C

The turbidity 1.1 FTU

TEST No. 3

The temperature 45°C

The turbidity 1.2 FTU

TEST No. 4

The temperature 55°C

The turbidity 3.0 FTU

TEST No. 5

The temperature 65°C

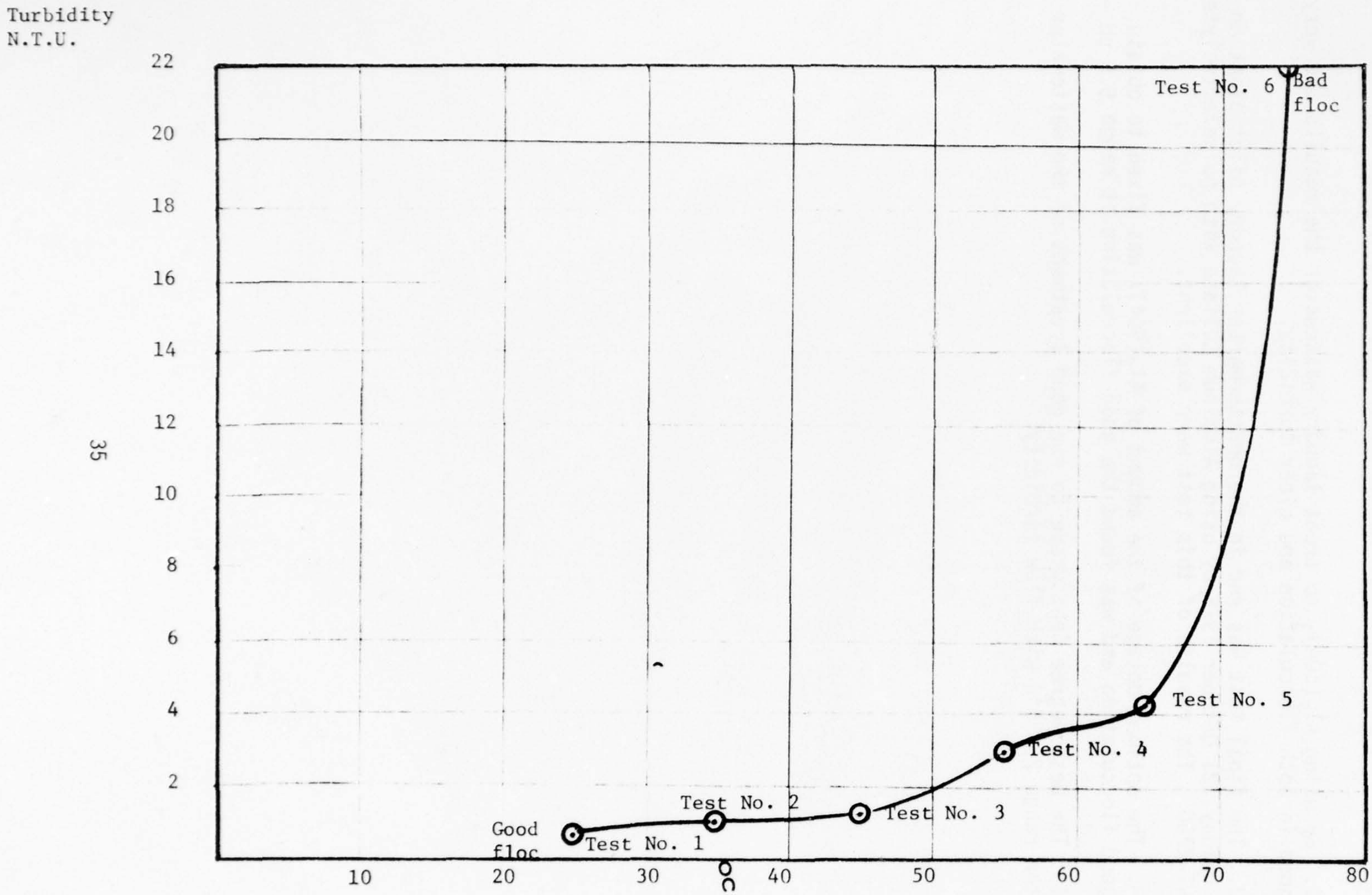
The turbidity 4.2 FTU

TEST No. 6

The temperature 75°C

The turbidity 22 FTU

Bad flocculation. (See Fig. No. 7)



Turbidity
N.T.U.
22
20
18
16
14
12
10
8
6
4
2
10
20
30
40
50
60
70
80
°C
Good
floc
Test No. 1
Test No. 2
Test No. 3
Test No. 4
Test No. 5
Test No. 6
Bad
floc


FIGURE NO. 7

# FINAL CONCLUSION

1. By using $Al_2(SO4)_3$ to treat laundry wastewater the results are very good in both flocculation and clear turbidity.

2. The final test was run in the quartermaster laundry pilot plant on Tuesday, 21 October 1975, by using Aluminum Sulfate with polyelectrolyte WT-2700. The results of this test were excellent.

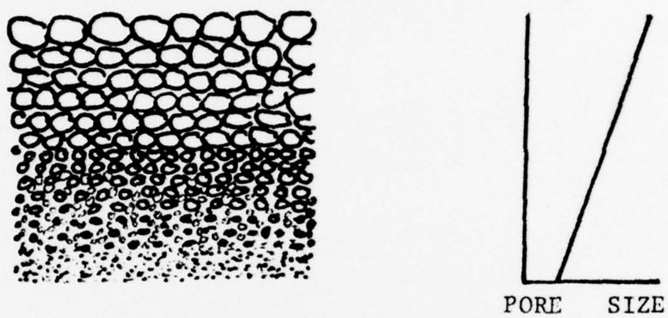
3. The optimum dosage of the amount of $Al_2(SO4)_3$ was fixed to obtain good flocculation and was found the good flocculation at range 5.5 pH - 6.5 pH.

4. The best degree Centigrade to run good treatment of the wastewater is the range 25-35°C with flow turbidity.

# PART 2

# FILTRATION

The ideal sand filter.




Cross section through ideal filter uniformly graded from coarse to fine from top to bottom.

In designing a dual media bed, it is desirable to have the coal (specific gravity about 1.6) as coarse as is consistent with solids removal to prevent surface blinding but have the sand (specific gravity about 2.6) as fine as possible to provide maximum solids removal. However, if the sand is too fine in relation to the coal, the former will actually rise above the top of the coal during the first backwash and remain there when the filter is returned to service.

Experience has shown that it is not feasible to use silica sand smaller than about 0.4 mm because smaller sand would require coal small enough to result in unacceptably high head loss at rates above gpm/ft$^2$ .

The problem of keeping a very fine medium at the bottom of the filter is overcome by using a third, very heavy 1 garnet, specific gravity of about 4.2, or ilmenite (specific gravity of about 4.5) very fine material beneath the coal and sand. Actually, the term "coarse-to-fine" filter refers more accurately to the pore space rather than to the media particles themselves.

A typical mixed-media filter has a particle size gradation which decreases from about 2 mm at the top to about 0.15 mm at the bottom. The uniform decrease in pore space with filter depth allows the entire filter depth to be utilized for floc removal and storage. Figure 1 shows how particles of the different media are actually mixed throughout the bed. At all points in the bed there is some of each component, but the percentage of each changes with bed depth. There is steadily increasing efficiency of filtration in the direction of the flow.

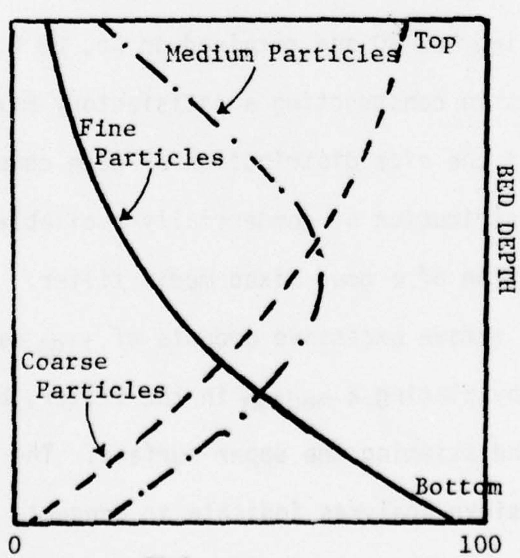



FIG № 1

Removal of the poorly flocculated solids normally found in a trickling filter effluent can be improved by using smaller media than would be used for removal of activated sludge effluent suspended solids. Pilot texts of various media designs can be more than justified by improved plant performance in most cases.

Table 1. Illustration of varying media design for various types of floc removal.

| Type of Application | Garnet | | Silica Sand | | Coal | |
|---|---|---|---|---|---|---|
| | Size | Depth | Size | Depth | Size | Depth |
| Very heavy loading of fragil floc | -40 +80 | 8 in. | -20 +40 | 12 in. | -10 +20 | 22 in. |
| Moderate loading of very strong floc | -20 +40 | 3 in. | -10 +20 | 12 in. | -10 +16 | 15 in. |
| Moderate loading of fragil floc | -40 +80 | 3 in. | -20 +40 | 9 in. | -10 +20 | 8 in. |

Size: -40 +80 = passing No. 40 and retained on No. 80 U.S. sieves.

One of the key factors in constructing a satisfactory mixed media bed is the careful control of the size distribution of each component medium. Rarely is the size distribution of commercially available materials adequate for construction of a good mixed media filter. The common problem is failure to remove excessive amounts of fine materials. These fines can be removed by placing a medium in the filter, backwashing it, draining the filter and skimming the upper surface. The procedure is repeated until field sieve analyses indicate an adequate particle size distribution has been obtained. A second medium is added and the procedure repeated. The third medium is then added and the entire procedure repeated.

Sometimes, 20-30 percent of the materials may have to be skimmed and discarded to achieve the proper particle size distribution.

## Use of Polymers as Filtration Aids

Polymers are high molecular weight, water soluble compounds which can be used as primary coagulants, settling aids, or filtration aids. They may be cationic, anionic, or anionic in charge. Generally, the doses required for coagulation or as a settling aid in conjunction with another coagulant far exceed that needed as a filtration aid. Typical doses when used as a settling aid are 0.1 - 2.0 mg/l while doses of less than 0.1 mg/l are often adequate to serve as a filtration aid. When used as a filtration aid, the polymer is added to increase the strength of the chemical floc and to control the depth of penetration of floc into the filter.

The polymer is not added to improve coagulation but rather to strengthen the floc made up of previously coagulated material to minimize the prospects of shearing fragile floc, causing filter breakthrough. For maximum effectiveness as a filtration aid, the polymer should be added directly to the filter influent and not in an upstream settling basin or flocculator. However, if polymers are used upstream as settling aids, it may not be necessary to add any additional polymer as filtration aid. Figure 2 illustrates the effects of polymers as filter aids. The condition represented by Figure 2A illustrates the results of a fragile floc steering and then penetrating the filter causing a premature termination of its run due to breakthrough of excessively high effluent turbidity.

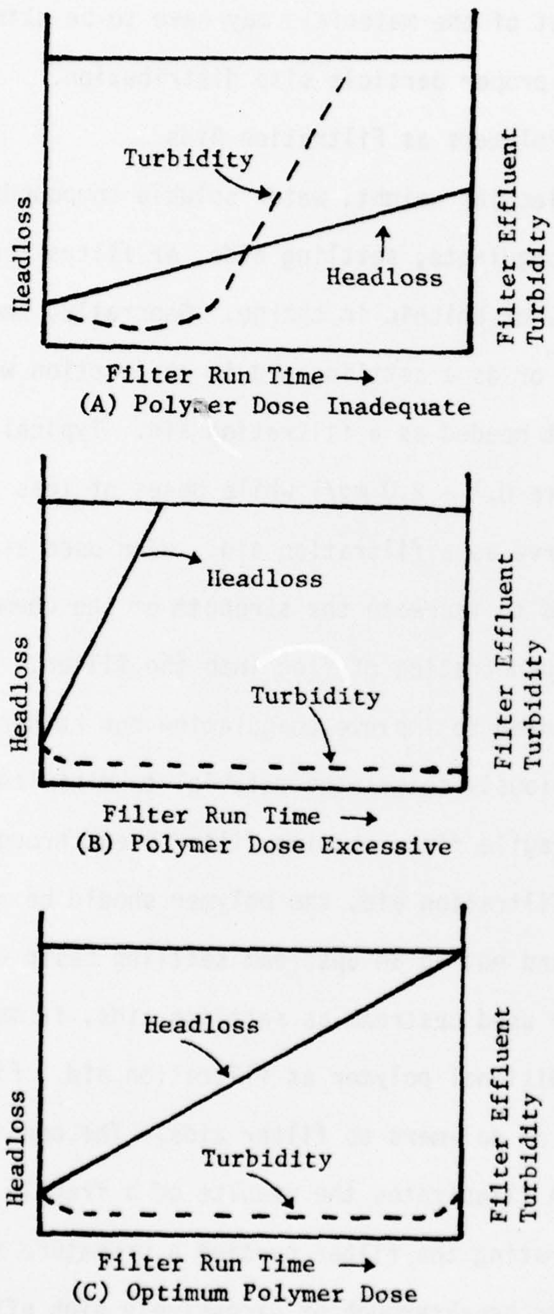



FIGURE NO. 2

Effect of polymers as filtration aids

If the polymer is too high (Figure 2B), the floc is too strong to permit penetration into the filter causing a rapid buildup of headloss in the upper portion of the filter and a premature termination due to excessive headloss. The optimum polymer dose will permit the terminal headloss to be reached simultaneously with the first sign of increasing filter effluent turbidity (Figure 2C).

## Types of Filter Structures

The gravity and pressure filter structures commonly used in water treatment plants are readily adaptable to advanced wastewater treatment plant filtration. Pressure filters are often advantageous in waste treatment applications for the following reasons:

1. In many wastewater applications, the applied solids loading is higher and more variable than in a water treatment application. Thus it is desirable to have higher heads (up to 20 ft.) available than practical with gravity filter designs to provide maximum operating flexibility.

2. In advanced waste treatment processes, the filtration step is frequently followed by another unit process (carbon absorption, ion exchange, etc.). The effluent from a pressure filter can be passed through a downstream process without having to pump the filter effluent, often eliminating a pumping step which would be required with a gravity filter.

3. All filter wash water must be treated sewage applications. The ability to operate to higher head losses with a pressure filter reduces the amount of wash water to be recycled.

4. Pressure filter systems are usually less costly in small and medium sized plants.

A typical gravity filter section is shown in Figure 3. Gravity filter areas usually do not exceed 800-1000 sq ft per filter unit. Two filter units may be combined in one structural cell.

Pressure filters may be either horizontal or vertical. The horizontal filter offers much larger filter area per unit and would normally be used when plant capacities exceed 1-1.5 mgd.

A typical horizontal pressure filter vessel is shown in Figure 4. Although an 8 ft diameter vessel is shown, 10 ft diameters are also commonly used with lengths up to 60 ft.

A typical vertical filter is shown in Figure 5. Diameter up to 11 ft are commonly used with working pressures up to 150 psig.

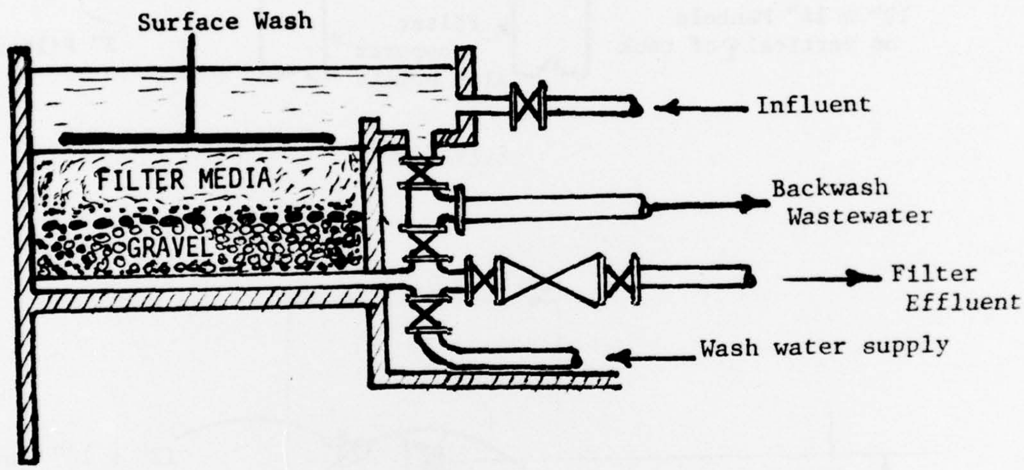
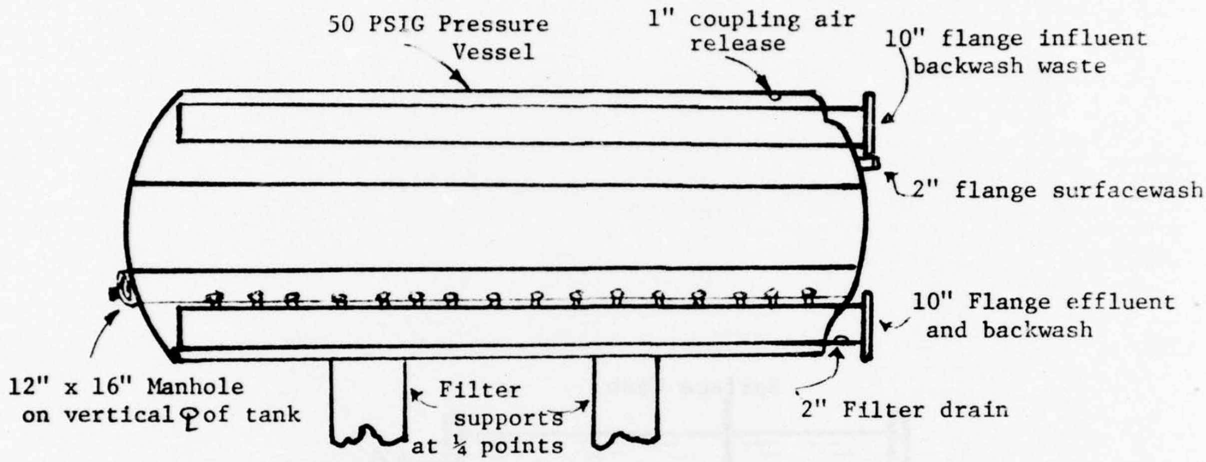
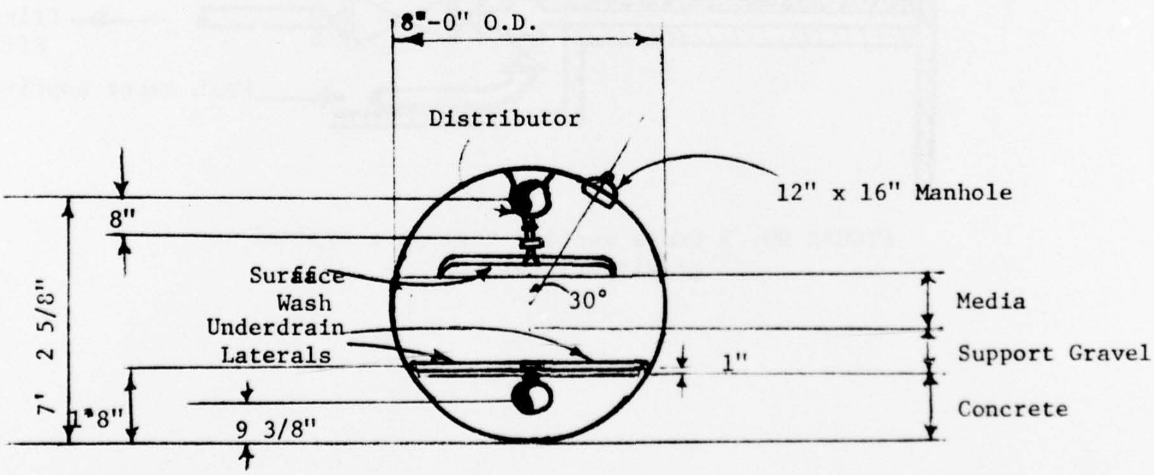



FIGURE NO. 3 Cross section through a typical gravity filter

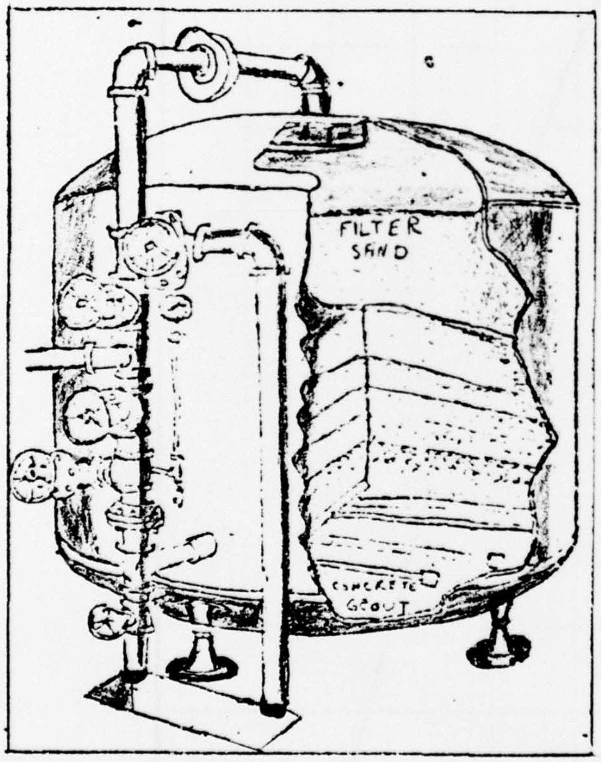



ELEVATION



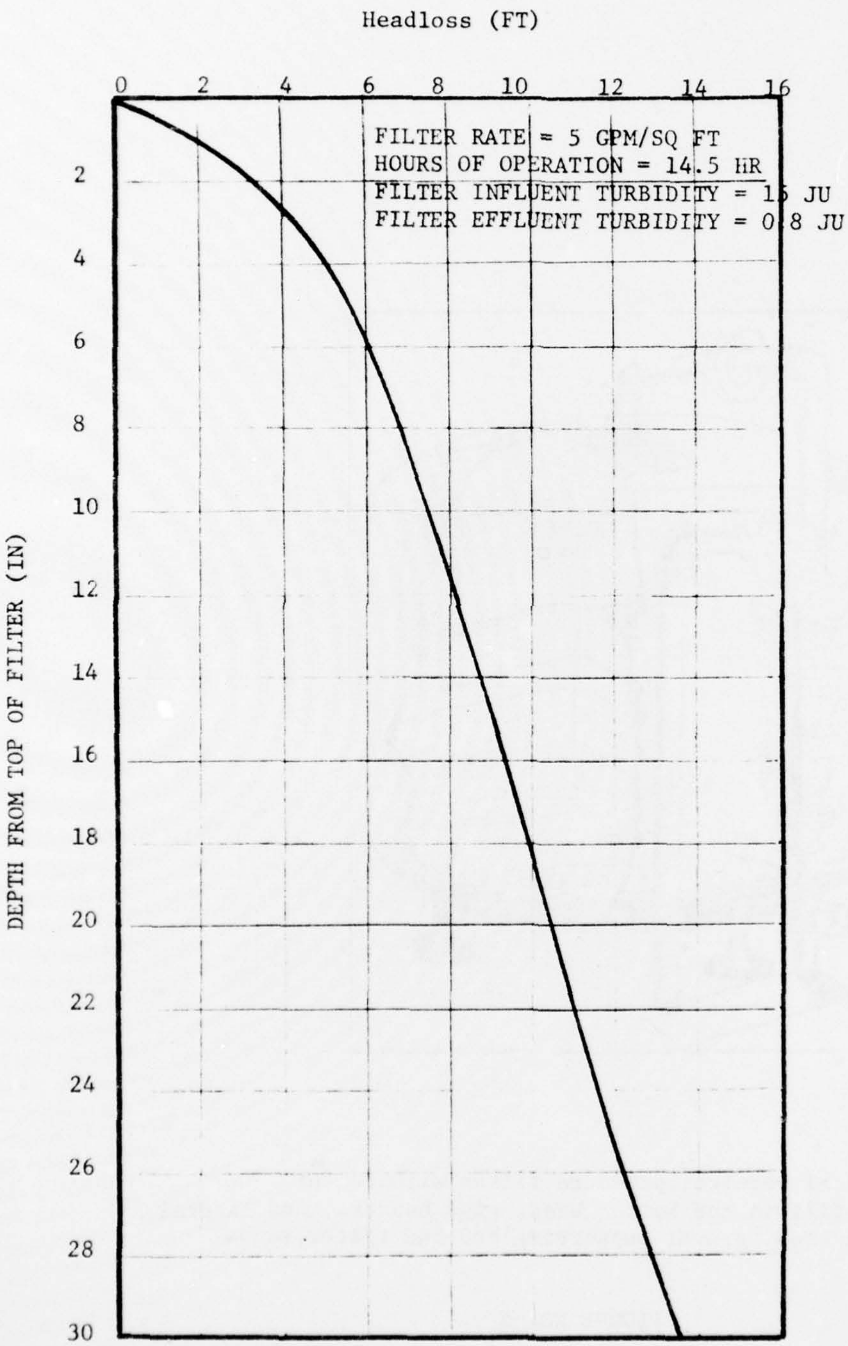

SECTION

FIGURE NO. 4 TYPICAL PRESSURE FILTER




A typical vertical pressure filter with cement grout fill in the bottom head, pipe headers, and lateral underdrains, gravel supporting bed and filter sands

FIGURE NO. 5




Headloss distribution in mixed media filter applied to activated sludge effluent

FIGURE 6

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2. 1974 Annual Book of ASTM Standards.

3. Process design manual for Phosphorus Removal for US Environmental Protection Agency Technology Transfer by Black, Veatch Consulting Engineers, Oct. 1971.

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